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FOIA b7 - 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20

figure of the second Raman amplifier fiber, and at least a portion of the plurality of signal wavelengths  $\lambda_s$  of the second Raman amplifier fiber having a gain level of at least 5 dB;

a signal input port coupled to the optical fiber;

a signal output port coupled to the optical fiber;

a pump input port coupled to the optical fiber;

a first lossy member coupled to the optical fiber and positioned between the first and second lengths of Raman amplifier fiber, the first lossy member being lossy in at least one direction; and

a pump shunt coupled to the optical fiber, wherein at least a portion of the one or more pump wavelengths  $\lambda_p$  is coupled between the first length of Raman amplifier fiber and the second length of Raman amplifier fiber.

2. The multi-stage optical amplifier of claim 1, wherein the pump input port is positioned between the first and second lengths of Raman amplifier fiber.

3. The multi-stage optical amplifier of claim 1, wherein the pump shunt is coupled to the signal input port and the signal output port.

4. The multi-stage optical amplifier of claim 1, further comprising:

a distributed Raman amplifier coupled to the signal input port.

5. The multi-stage optical amplifier of claim 4, wherein at least a portion of the pump shunt is positioned between the distributed Raman amplifier and the signal input port.

6. The multi-stage optical amplifier of claim 1, wherein the first and second lengths of Raman amplifier fiber each have a length greater than or equal to 200m.

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FOI b7E b7F b7G b7H b7I b7J b7K b7L b7M b7N b7O b7P b7Q b7R b7S b7T b7U b7V b7W b7X b7Y b7Z

1 7. The multi-stage optical amplifier of claim 1, wherein the one or more  
2 pump wavelengths  $\lambda_p$  are in the range of 1300 to 1530 nm.

1 8. The multi-stage optical amplifier of claim 1, wherein the plurality of  
2 signal wavelengths  $\lambda_s$  is in the range of 1430 to 1530 nm.

1 9. The multi-stage optical amplifier of claim 1, wherein the first lossy  
2 member is an optical isolator.

1 10. The multi-stage optical amplifier of claim 1, wherein the first lossy  
2 member is an add/drop multiplexer.

1 11. The multi-stage optical amplifier of claim 1, wherein the first lossy  
2 member is a gain equalization member.

1 12. The multi-stage optical amplifier of claim 1, wherein the first lossy  
2 member is a dispersion compensation element.

1 13. The multi-stage optical amplifier of claim 1, wherein at least a portion of  
2 at least one of the first and second Raman amplifier fibers is a dispersion compensating  
3 fiber.

1 14. The multi-stage optical amplifier of claim 13, wherein at least a portion  
2 of the first and second Raman amplifier fibers are dispersion compensating fibers.

1 15. The multi-stage optical amplifier of claim 1, wherein the second length  
2 of amplifier fiber has a higher gain than the first length of amplifier fiber.

1 16. The multi-stage optical amplifier of claim 3, further comprising:  
2 at least one WDM coupler to couple a pump path from the signal input  
3 port to the signal output port.

1 17. The multi-stage optical amplifier of claim 1, further comprising:  
2 a pump source coupled to the pump input port.

1 18. The multi-stage optical amplifier of claim 1, further comprising:  
2 at least one laser diode pump source coupled to the pump input port.

1 19. The multi-stage optical amplifier of claim 1, further comprising:  
2 a second lossy member coupled to the pump shunt.

1 20. The multi-stage optical amplifier of claim 1, wherein the pump shunt  
2 includes an optical fiber.

1 21. A multi-stage optical amplifier, comprising:  
2 an optical fiber including a first length of Raman amplifier fiber and a second length of  
3 Raman amplifier fiber, the optical fiber configured to be coupled to a signal source that  
4 produces a plurality of signal wavelengths  $\lambda_s$ , and a pump source that produces one or  
5 more pump wavelengths  $\lambda_p$ , the one or more pump wavelengths  $\lambda_p$  being less than at  
6 least a portion of the plurality of signal wavelengths  $\lambda_s$ , and an optical fiber cut-off  
7 wavelength of at least one of the first length of Raman amplifier fiber and the second  
8 length of Raman amplifier fiber that is less than the one or more pump wavelengths  $\lambda_p$ ;  
9 a signal input port coupled to the optical fiber;  
10 a signal output port coupled to the optical fiber;  
11 a pump input port coupled to the optical fiber;  
12 a first lossy member coupled to the optical fiber and positioned between the first  
13 and second lengths of Raman amplifier fiber, the first lossy member being lossy in at  
14 least one direction; and  
15 a pump shunt coupled to the optical fiber, wherein at least a portion of the one or more  
16 pump wavelengths  $\lambda_p$  is coupled between the first length of Raman amplifier fiber and  
17 the second length of Raman amplifier fiber.

1 22. The multi-stage optical amplifier of claim 21, wherein the pump input  
2 port is positioned between the first and second lengths of Raman amplifier fiber.

1 23. The multi-stage optical amplifier of claim 21, wherein the pump shunt is  
2 coupled to the signal input port and the signal output port.

1 24. The multi-stage optical amplifier of claim 21, wherein optical fiber cut-  
2 off wavelengths of the first length of Raman amplifier fiber and the second length of  
3 Raman amplifier fiber are less than the one or more pump wavelengths  $\lambda_p$ .

1 25. The multi-stage optical amplifier of claim 21, further comprising:  
2 a distributed Raman amplifier coupled to the signal input port.

1 26. The multi-stage optical amplifier of claim 25, wherein at least a portion of  
2 the pump shunt is positioned between the distributed Raman amplifier and the signal  
3 input port.

1 27. The multi-stage optical amplifier of claim 1, wherein the first and  
2 second lengths of Raman amplifier fiber each have a length greater than or equal to  
3 200m.

1 28. The multi-stage optical amplifier of claim 1, wherein the one or more  
2 pump wavelengths  $\lambda_p$  are in the range of 1300 to 1530 nm.

1 29. The multi-stage optical amplifier of claim 1, wherein the plurality of  
2 signal wavelengths  $\lambda_s$  is in the range of 1430 to 1530 nm.

1 30. The multi-stage optical amplifier of claim 1, wherein the first lossy  
2 member is an optical isolator.

1 31. The multi-stage optical amplifier of claim 1, wherein the first lossy  
2 member is an add/drop multiplexer.

1 32. The multi-stage optical amplifier of claim 1, wherein the first lossy  
2 member is a gain equalization member.

1 33. The multi-stage optical amplifier of claim 1, wherein the first lossy  
2 member is a dispersion compensation element.

1 34. The multi-stage optical amplifier of claim 1, wherein at least a portion of  
2 at least one of the first and second Raman amplifier fibers is a dispersion compensating  
3 fiber.

1 35. The multi-stage optical amplifier of claim 34, wherein at least a portion  
2 of the first and second Raman amplifier fibers are dispersion compensating fibers.

1 36. The multi-stage optical amplifier of claim 1, wherein the second length  
2 of amplifier fiber has a higher gain than the first length of amplifier fiber.

1 37. The multi-stage optical amplifier of claim 1, further comprising:  
2 at least one WDM coupler to couple a pump path from the signal input  
3 port to the signal output port.

1 38. The multi-stage optical amplifier of claim 1, further comprising:  
2 a pump source coupled to the pump input port.

1 39. The multi-stage optical amplifier of claim 1, further comprising:  
2 at least one laser diode pump source coupled to the pump input port.

1 40. The multi-stage optical amplifier of claim 1, further comprising:  
2 a second lossy member coupled to the pump shunt.

1 41. The multi-stage optical amplifier of claim 1, wherein the pump shunt  
2 includes an optical fiber.

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FOOTNOTES

1 42. A multi-stage optical amplifier, comprising:

2 an optical fiber including a first length of Raman amplifier fiber and a second  
3 length of Raman amplifier fiber, the optical fiber configured to be coupled to a signal  
4 source that produces a plurality of signal wavelengths  $\lambda_s$  and a pump source that  
5 produces one or more pump wavelengths  $\lambda_p$ , the one or more pump wavelengths  $\lambda_p$   
6 being less than at least a portion of the plurality of signal wavelengths  $\lambda_s$ , wherein at  
7 least a portion of at least one of the first length of Raman amplifier fiber and the second  
8 length of Raman amplifier fiber is a dispersion compensating fiber;

9 a signal input port coupled to the optical fiber;

10 a signal output port coupled to the optical fiber;

11 a pump input port coupled to the optical fiber;

12 a first lossy member coupled to the optical fiber and positioned between the first  
13 and second lengths of Raman amplifier fiber, the first lossy member being lossy in at  
14 least one direction; and

15 a pump shunt coupled to the optical fiber, wherein at least a portion of the one  
16 or more pump wavelengths  $\lambda_p$  is coupled between the first length of Raman amplifier  
17 fiber and the second length of Raman amplifier fiber.

1 43. The multi-stage optical amplifier of claim 42, wherein the pump input  
2 port is positioned between the first and second lengths of Raman amplifier fiber.

1 44. The multi-stage optical amplifier of claim 42, wherein an optical fiber  
2 cut-off wavelength of at least one of the first length of Raman amplifier fiber and the  
3 second length of Raman amplifier fiber is less than the one or more pump wavelengths  
4  $\lambda_p$ .

1 45. The multi-stage optical amplifier of claim 42, wherein at least a portion  
2 of the first length of Raman amplifier fiber and the second length of Raman amplifier  
3 fiber are dispersion compensating fibers.

1 46. The multi-stage optical amplifier of claim 42, wherein the dispersion  
2 compensating fiber has a magnitude of dispersion of at least 50 psec/(nm) (km) for at  
3 least a portion  
4 of the plurality of signal wavelengths  $\lambda_s$ .

1 47. The multi-stage optical amplifier of claim 42, wherein the dispersion  
2 compensating fiber has a magnitude of dispersion less than 50 psec/(nm) (km) for at  
3 least a portion  
4 of the plurality of signal wavelengths  $\lambda_s$ .

1 48. The multi-stage optical amplifier of claim 42, further comprising:  
2 a distributed Raman amplifier coupled to the signal input port.

1 49. The multi-stage optical amplifier of claim 48, wherein at least a portion of  
2 the pump shunt is positioned between the distributed Raman amplifier and the signal  
3 input port.

1 50. A multi-stage optical amplifier, comprising:  
2 an optical fiber including a first length of Raman amplifier fiber and a second  
3 length of Raman amplifier fiber, the optical fiber configured to be coupled to a signal  
4 source that produces a plurality of signal wavelengths  $\lambda_s$  and a pump source that  
5 produces one or more pump wavelengths  $\lambda_p$ , the one or more pump wavelengths  $\lambda_p$   
6 being less than at least a portion of the plurality of signal wavelengths  $\lambda_s$ ;

7 a signal input port coupled to the optical fiber;

8 a signal output port coupled to the optical fiber;

9 a pump input port coupled to the optical fiber;

10 a first lossy member coupled to the optical fiber and positioned between the first  
11 and second lengths of Raman amplifier fiber, the first lossy member being lossy in at  
12 least one direction;

13 a pump shunt coupled to the optical fiber, wherein at least a portion of  
14 the one or more pump wavelengths  $\lambda_p$  is coupled between the first length of Raman  
15 amplifier fiber and the second length of Raman amplifier fiber; and

16 at least a first pump source coupled to pump input port, the at least first pump  
17 source including multiple pump sources with outputs that are combined using at least  
18 one of wavelength and polarization multiplexing.

1 51. The multi-stage optical amplifier of claim 50, wherein the pump input  
2 port is positioned between the first and second lengths of Raman amplifier fiber.

1 52. The multi-stage optical amplifier of claim 50, wherein the pump shunt is  
2 coupled to the signal input port and the signal output port.

1 53. The multi-stage optical amplifier of claim 50, wherein the at least first  
2 pump source includes multiple pump sources with outputs that are combined using  
3 wavelength and polarization multiplexing.

1 54. The multi-stage optical amplifier of claim 50, further comprising:

2 a distributed Raman amplifier coupled to the signal input port.

1 55. The multi-stage optical amplifier of claim 54, wherein at least a portion of  
2 the pump shunt is positioned between the distributed Raman amplifier and the signal  
3 input port.

1 56. A multi-stage optical amplifier system, comprising:

2 a plurality of transmitters that produce a plurality of signal wavelengths  $\lambda_s$ ;



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a multi-stage optical amplifier including,

an optical fiber with a first length of Raman amplifier fiber and a second length of Raman amplifier fiber, the optical fiber coupled to the plurality of transmitters and configured to be coupled to a pump source that produces one or more pump wavelengths  $\lambda_p$ , wherein the one or more pump wavelengths  $\lambda_p$  are less than at least a portion of the plurality of signal wavelengths  $\lambda_s$ , at least a portion of the plurality of wavelengths  $\lambda_s$  of the first Raman amplifier fiber having an optical noise figure of less than 8 dB and less than an optical noise figure of the second Raman amplifier fiber, and at least a portion of the plurality of signal wavelengths  $\lambda_s$  of the second Raman amplifier fiber having a gain level of at least 5 dB;

a signal input port coupled to the optical fiber,

a signal output port coupled to the optical fiber;

a pump input port coupled to the optical fiber;

a first lossy member coupled to the optical fiber and positioned between the first and second lengths of Raman amplifier fiber, the first lossy member being lossy in at least one direction,

a pump shunt coupled to the optical fiber, wherein at least a portion of the one or more pump wavelengths  $\lambda_p$  is coupled between the first length of Raman amplifier fiber and the second length of Raman amplifier fiber; and

a plurality of receivers coupled to the multi-stage optical amplifier.

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1 57. The multi-stage optical amplifier system of claim 56, wherein the pump  
2 input port is positioned between the first and second lengths of Raman amplifier fiber.

1 58. The multi-stage optical amplifier system of claim 56, wherein the pump  
2 shunt is coupled to the signal input port and the signal output port.

1 59. The multi-stage optical amplifier system of claim 56, further comprising:  
2 a distributed Raman amplifier coupled to the signal input port.

1 60. The multi-stage optical amplifier system of claim 59, wherein at least a  
2 portion of the pump shunt is positioned between the distributed Raman amplifier and  
3 the signal input port.

1 61. The multi-stage optical amplifier system of claim 56, wherein the multi-  
2 stage optical amplifier is an in-line amplifier.

1 62. The multi-stage optical amplifier system of claim 56, wherein the multi-  
2 stage optical amplifier is a booster amplifier.

1 63. The multi-stage optical amplifier system of claim 56, wherein the multi-  
2 stage optical amplifier is a pre-amplifier.

1 64. The multi-stage optical amplifier system of claim 56, wherein the  
2 plurality of receivers are directly coupled to the multi-stage optical amplifier.

1 65. A multi-stage optical amplifier system, comprising:  
2 a plurality of transmitters that produce a plurality of signal wavelengths  
3  $\lambda_s$   
4 a multi-stage optical amplifier, including,

5 an optical fiber including a first length of Raman  
6 amplifier fiber and a second length of Raman amplifier fiber, the  
7 optical fiber coupled to the plurality of transmitters and

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8 configured to be coupled to a pump source that produces one or  
9 more pump wavelengths  $\lambda_p$ , the one or more pump wavelengths  
10  $\lambda_p$  being less than at least a portion of the plurality of signal  
11 wavelengths  $\lambda_s$ , and an optical fiber cut-off wavelength of at least  
12 one of the first length of Raman amplifier fiber and the second  
13 length of Raman amplifier fiber that is less than the one or more  
14 pump wavelengths  $\lambda_p$ ,

15 a signal input port coupled to the optical fiber,

16 a signal output port coupled to the optical fiber,

17 a pump input port coupled to the optical fiber,

18 a first lossy member coupled to the optical fiber and  
19 positioned between the first and second lengths of Raman  
20 amplifier fiber, the first lossy member being lossy in at least one  
21 direction,

22 a pump shunt coupled to the optical fiber, wherein at least  
23 a portion of the one or more pump wavelengths  $\lambda_p$  is coupled  
24 between the first length of Raman amplifier fiber and the second  
25 length of Raman amplifier fiber; and

26 a plurality of receivers coupled to the multi-stage optical amplifier.

1 66. The multi-stage optical amplifier system of claim 65, wherein the pump  
2 input port is positioned between the first and second lengths of Raman amplifier fiber.

1 67. The multi-stage optical amplifier system of claim 65, wherein the pump  
2 shunt is coupled to the signal input port and the signal output port.

1 68. The multi-stage optical amplifier system of claim 65, wherein optical  
2 fiber cut-off wavelengths of the first length of Raman amplifier fiber and the second  
3 length of Raman amplifier fiber are less than the one or more pump wavelengths  $\lambda_p$ .

1 69. The multi-stage optical amplifier system of claim 65, further comprising:  
2 a distributed Raman amplifier coupled to the signal input port.

1 70. The multi-stage optical amplifier system of claim 69, wherein at least a  
2 portion of the pump shunt is positioned between the distributed Raman amplifier and  
3 the signal input port.

1 71. The multi-stage optical amplifier system of claim 69, wherein the multi-  
2 stage optical amplifier is an in-line amplifier.

1 72. The multi-stage optical amplifier system of claim 69, wherein the multi-  
2 stage optical amplifier is a booster amplifier.

1 73. The multi-stage optical amplifier system of claim 69, wherein the multi-  
2 stage optical amplifier is a pre-amplifier.

1 74. The multi-stage optical amplifier system of claim 69, wherein the  
2 plurality of receivers are directly coupled to the multi-stage optical amplifier.

1 75. A multi-stage optical amplifier system, comprising:

2 a plurality of transmitters that produce a plurality of signal wavelengths  $\lambda_s$ ;  
3 a multi-stage optical amplifier including,

4 an optical fiber including a first length of Raman amplifier fiber  
5 and a second length of Raman amplifier fiber, the optical fiber coupled  
6 to the plurality of transmitters and configured to be coupled to a pump  
7 source that produces one or more pump wavelengths  $\lambda_p$ , the one or more  
8 pump wavelengths  $\lambda_p$  being less than at least a portion of the plurality of  
9 signal wavelengths  $\lambda_s$ , wherein at least a portion of at least one of the  
10 first length of Raman amplifier fiber and the second length of Raman  
11 amplifier fiber is a dispersion compensating fiber,

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12 a signal input port coupled to the optical fiber,  
13 a signal output port coupled to the optical fiber,  
14 a pump input port coupled to the optical fiber,  
15 a first lossy member coupled to the optical fiber and positioned  
16 between the first and second lengths of Raman amplifier fiber, the first  
17 lossy member being lossy in at least one direction,  
18 a pump shunt coupled to the optical fiber, wherein at least a  
19 portion of the one or more pump wavelengths  $\lambda_p$  is coupled between the  
20 first length of Raman amplifier fiber and the second length of Raman  
21 amplifier fiber; and  
22 a plurality of receivers coupled to the multi-stage optical amplifier.

1 76. The multi-stage optical amplifier system of claim 75, wherein the pump  
2 input port is positioned between the first and second lengths of Raman amplifier fiber.

1 77. The multi-stage optical amplifier system of claim 75, wherein an optical  
2 fiber cut-off wavelength of at least one of the first length of Raman amplifier fiber and  
3 the second length of Raman amplifier fiber is less than the one or more pump  
4 wavelengths  $\lambda_p$ .

1 78. The multi-stage optical amplifier system of claim 75, wherein at least a  
2 portion of the first length of Raman amplifier fiber and the second length of Raman  
3 amplifier fiber are dispersion compensating fibers.

1 79. The multi-stage optical amplifier system of claim 75, wherein the  
2 dispersion compensating fiber has a magnitude of dispersion greater than 50 psec/(nm)  
3 -(km) for at least a portion of the plurality of signal wavelengths  $\lambda_s$ .

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1 80. The multi-stage optical amplifier system of claim 75, wherein the  
2 dispersion compensating fiber has a magnitude of dispersion less than 50 psec/(nm)  
3 (km) for at least a portion  
4 of the plurality of signal wavelengths  $\lambda_s$ .

1 81. The multi-stage optical amplifier system of claim 75, further comprising:  
2 a distributed Raman amplifier coupled to the signal input port.

1 82. The multi-stage optical amplifier system of claim 81, wherein at least a  
2 portion of the pump shunt is positioned between the distributed Raman amplifier and  
3 the signal input port.

1 83. The multi-stage optical amplifier system of claim 75, wherein the multi-  
2 stage optical amplifier is an in-line amplifier.

1 84. The multi-stage optical amplifier system of claim 75, wherein the multi-  
2 stage optical amplifier is a booster amplifier.

1 85. The multi-stage optical amplifier system of claim 75, wherein the multi-  
2 stage optical amplifier is a pre-amplifier.

1 86. The multi-stage optical amplifier system of claim 75, wherein the  
2 plurality of receivers are directly coupled to the multi-stage optical amplifier.

1 87. A multi-stage optical amplifier system, comprising:

2 a plurality of transmitters that produce a plurality of signal wavelengths  $\lambda_s$ ;

3 a multi-stage optical amplifier including,

4 an optical fiber including a first length of Raman amplifier fiber  
5 and a second length of Raman amplifier fiber, the optical fiber coupled  
6 to the plurality of transmitters and configured to be coupled to a pump  
7 source that produces one or more pump wavelengths  $\lambda_p$ , the one or more

8 pump wavelengths  $\lambda_p$  being less than at least a portion of the plurality of  
9 signal wavelengths  $\lambda_s$ ,

10 a signal input port coupled to the optical fiber,

11 a signal output port coupled to the optical fiber,

12 a pump input port coupled to the optical fiber,

13 a first lossy member coupled to the optical fiber and positioned  
14 between the first and second lengths of Raman amplifier fiber, the first  
15 lossy member being lossy in at least one direction,

16 a pump shunt coupled to the optical fiber, wherein at least a  
17 portion of the one or more pump wavelengths  $\lambda_p$  is coupled between the  
18 first length of Raman amplifier fiber and the second length of Raman  
19 amplifier fiber,

20 at least a first pump source coupled to pump input port, the at  
21 least first pump source including multiple pump sources with outputs  
22 that are combined using at least one of wavelength and polarization  
23 multiplexing; and

24 a plurality of receivers coupled to the multi-stage optical amplifier.

1 88. The multi-stage optical amplifier system of claim 87, wherein the pump  
2 input port is positioned between the first and second lengths of Raman amplifier fiber.

1 89. The multi-stage optical amplifier system of claim 87, wherein the pump  
2 shunt is coupled to the signal input port and the signal output port.

1 90. The multi-stage optical amplifier system of claim 87, wherein at least  
2 first pump source includes multiple pump sources with outputs that are combined using  
3 wavelength and polarization multiplexing.

1 91. The multi-stage optical amplifier system of claim 87, further comprising:

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2 a distributed Raman amplifier coupled to the signal input port.

1 92. The multi-stage optical amplifier system of claim 91, wherein at least a  
2 portion of the pump shunt is positioned between the distributed Raman amplifier and  
3 the signal input port.

1 93. The multi-stage optical amplifier system of claim 87, wherein the multi-  
2 stage optical amplifier is an in-line amplifier.

1 94. The multi-stage optical amplifier system of claim 87, wherein the multi-  
2 stage optical amplifier is a booster amplifier.

1 95. The multi-stage optical amplifier system of claim 87, wherein the multi-  
2 stage optical amplifier is a pre-amplifier.

1 96. The multi-stage optical amplifier system of claim 87, wherein the  
2 plurality of receivers are directly coupled to the multi-stage optical amplifier.

1 97. A multi-stage optical amplifier, comprising:

2 an optical fiber including a first length of Raman amplifier fiber and a second  
3 length of Raman amplifier fiber, the optical fiber configured to be coupled to a signal  
4 source that produces a plurality of signal wavelengths  $\lambda_s$  and a pump source that  
5 produces one or more pump wavelengths  $\lambda_p$ , the one or more pump wavelengths  $\lambda_p$   
6 being less than at least a portion of the plurality of signal wavelengths  $\lambda_s$ , wherein at  
7 least a portion of at least one of the first length of Raman amplifier fiber and the second  
8 length of Raman amplifier fiber is a fiber with a selected small effective core area and  
9 high germanium doping to provide an enhancement of a Raman gain coefficient;

10 a signal input port coupled to the optical fiber;

11 a signal output port coupled to the optical fiber;

12 a pump input port coupled to the optical fiber;



13 a first lossy member coupled to the optical fiber and positioned between the first  
14 and second lengths of Raman amplifier fiber, the first lossy member being lossy in at  
15 least one direction; and

16 a pump shunt coupled to the optical fiber, wherein at least a portion of the one  
17 or more pump wavelengths  $\lambda_p$  is coupled between the first length of Raman amplifier  
18 fiber and the second length of Raman amplifier fiber.

1 98. The multi-stage optical amplifier of claim 97, wherein the pump input  
2 port is positioned between the first and second lengths of Raman amplifier fiber.

1 99. The multi-stage optical amplifier of claim 97, wherein an optical fiber  
2 cut-off wavelength of at least one of the first length of Raman amplifier fiber and the  
3 second length of Raman amplifier fiber is less than the one or more pump wavelengths  
4  $\lambda_p$ .

1 100. The multi-stage optical amplifier of claim 97, wherein at least a portion  
2 of at least one of the first length of Raman amplifier fiber and the second length of  
3 Raman amplifier fiber is a dispersion compensating fiber.

1 101. The multi-stage optical amplifier of claim 97, wherein at least a portion  
2 of at least one of the first length of Raman amplifier fiber and the second length of  
3 Raman amplifier fiber is a dispersion compensating fiber.

1 102. A multi-stage optical amplifier system, comprising:

2 a plurality of transmitters that produce a plurality of signal wavelengths  $\lambda_s$ ;

3 a multi-stage optical amplifier including,

4 an optical fiber including a first length of Raman amplifier fiber  
5 and a second length of Raman amplifier fiber, the optical fiber coupled  
6 to the plurality of transmitters and configured to be coupled to a pump  
7 source that produces one or more pump wavelengths  $\lambda_p$ , the one or more  
8 pump wavelengths  $\lambda_p$  being less than at least a portion of the plurality of

9 signal wavelengths  $\lambda_s$ , wherein at least a portion of at least one of the  
10 first length of Raman amplifier fiber and the second length of Raman  
11 amplifier fiber is a fiber with a selected small effective core area and  
12 high germanium doping to provide an enhancement of a Raman gain  
13 coefficient,

14 a signal input port coupled to the optical fiber,

15 a signal output port coupled to the optical fiber,

16 a pump input port coupled to the optical fiber,

17 a first lossy member coupled to the optical fiber and positioned  
18 between the first and second lengths of Raman amplifier fiber, the first  
19 lossy member being lossy in at least one direction,

20 a pump shunt coupled to the optical fiber, wherein at least a  
21 portion of the one or more pump wavelengths  $\lambda_p$  is coupled between the  
22 first length of Raman amplifier fiber and the second length of Raman  
23 amplifier fiber; and

24 a plurality of receivers coupled to the multi-stage optical amplifier.